Antenna Connections

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Artificial Ground: Part One

Welcome back, my friends. This month and next month, we're going on a little journey of discovery. Yes, your antenna columnist finally broke down and bought himself the MFJ 931 Artificial Ground. I've wanted to for a long time—and I finally got my hands on one! I found mine on eBay; it was part of an "estate sale," which generally means that a ham operator or SWL has passed on and didn't leave his/her radio equipment to anyone in a will, or else the inheritors are selling off the stuff they don't want or need.

This one looked good in the photos, so I made a dirt-cheap offer, which was immediately accepted. Whereas a new one will run you about $105, I got my lightly used one for $35, plus another $10 to ship it to me. But after you've read my account of its effectiveness, you'll agree that even the $105 that MFJ wants for a new one is money well spent.

It is a great mystery to me that no one else markets an artificial ground. It may be simply a matter of education; you can picture well-meaning antenna columnists (cough, cough) preaching endlessly to their flock that nothing will improve their results like a good RF ground. One would think that more than one manufacturer would perceive a viable market here. It only makes sense, intuitively and otherwise. If an antenna tuner can redeem the situation created by a random, short, low, or otherwise compromised antenna, then a ground tuner seems like it would accomplish the same thing on the other side. Indeed, the circuit of an artificial ground looks an awful lot like an antenna tuner circuit, and the goal is the same in both cases—to maximize RF current flow at the frequency in use.

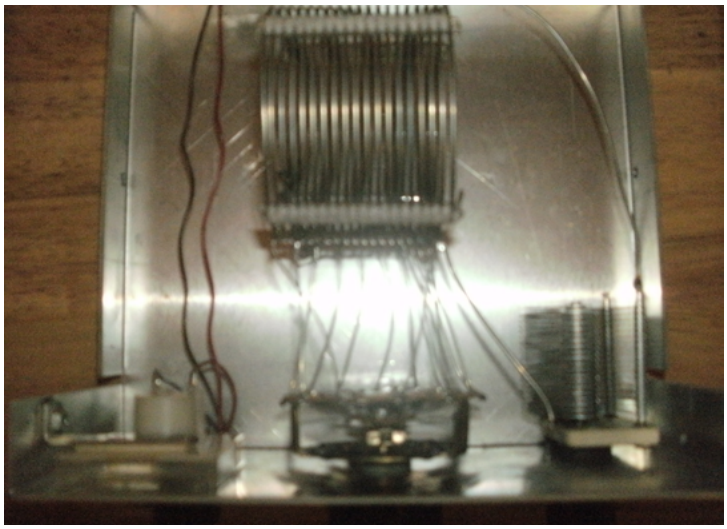
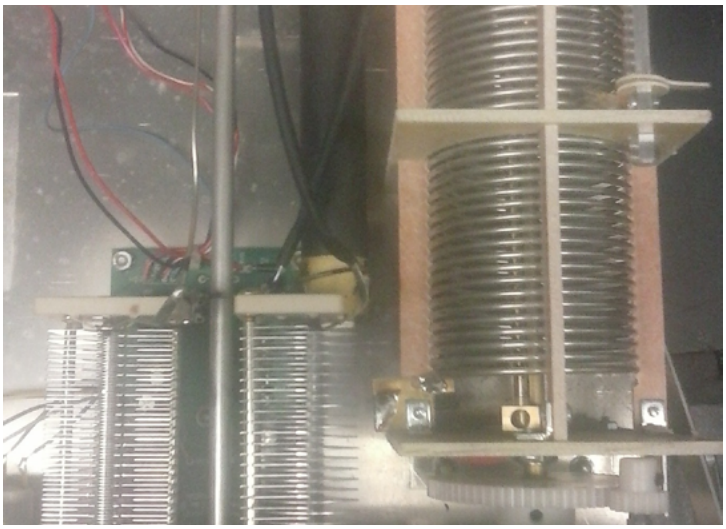
It is crucial to understand how important this flow of RF ground current is. If you're running some setup that is already balanced, so to speak, such as a dipole fed at its center with ladder line, then the RF current is already maximized in the antenna. But for a million and one "random" situations—a long-wire of very random length, or frequencies where a random dipole doesn't respond well because of its particular length, or odd, non-antenna-seeming objects (over the years, I have single-wire fed, among other things, metal rain gutters, metal window screens, an old king-size box spring stood on end on a balcony, and the metal chimney of an apartment furnace, to name a few)—the artificial ground can make spectacular improvements in antenna efficiency.

MFJ 931 artificial ground ($110). (Courtesy: MFJ Enterprises)

Nuts and Bolts

The first thing I did when I got the unit unpacked was to remove the outer cover and examine the interior. A number of reviewers of this unit have complained of finding cold or otherwise poor solder joints, so I wanted to check on that. This particular specimen did not appear to have any cold solder joints, but since I had the cover off I went ahead and got them all solder-melting hot with my trusty soldering gun. This is good practice with anything that, ah, someone other than yourself soldered up.

A look at the interior layout reveals how much like an antenna tuner the unit is; there's a tapped coil with a switch to select taps, a variable capacitor, and a meter circuit. This makes good intuitive sense, that the artificial ground closely resemble an antenna tuner; in both cases, we're trying to maximize the flow of RF current. This may be a new step in your thinking. Most of us can easily visualize that maximizing the flow of RF to the antenna means maximum transmitted power and best receive sensitivity; the step to understanding ground is a little trickier. I think it's simply a case of education, and we're not to blame; the writers who told us for years and years to make a good ground by connecting a wire to the nearest cold water pipe had good intentions, but they made the fatal mistake of confusing a good SAFETY ground with a good RF ground. RF ground, you see, has no more to do with connecting electrically to the Earth's crust than an antenna has to do with making a good electrical connection to the sky. As I've said before, this is one of those

Interior of MFJ 931 Artificial Ground….and interior of MFJ 969 tuner. Hey, they're both tuners! (Photos by author)

situations where the term "ground" is unfortunate, since it has nothing to do with the safety ground whose importance we've all had drilled into our heads. Look at it this way: Maximum RF flow in an antenna gives us the best results; intuitively, it makes sense that maximizing RF current flow on the ground side of an unbalanced antenna will make our results ever so much better. Ground is an IMAGE that balances the image presented by the antenna, and maximum RF current flows.

A Question of Balance

One way to simplify understanding this is to think about the systems where an artificial ground is not needed. Consider the humble dipole. Even fed with coaxial cable, a dipole at resonance has an exact quarter-wavelength connected to the "hot" of the coax—and an exact quarter-wavelength connected to the ground braid of the coax. Once you notice this, it is awfully hard not to visualize the dipole as a horizontal quarter-wave radiator, with a quarter-wave ground radial in line with it. This is a BALANCED arrangement. An artificial RF ground will not help this scenario, since it is by definition as good as it can be; maximum RF current flows to both sides of the dipole simply by dint of it being two quarter-wavelengths, connected to hot and to ground.

Any other antennas that are built off of the dipole concept will show this same balance. A Yagi is a good place to start; after all, its driven element is just a dipole. It's a bit different, because a Yagi usually has a metal boom which the elements are directly mounted to, lowering feed-point impedance; some matching at the transition from feedline to antenna is needed, since this all-metal arrangement typically shows about 20 ohms impedance, rather than the 50 ohms the coax would prefer to see. But this does not change the basic fact that the driven element is a dipole, and thus we have a balanced arrangement.

Antennas built off the loop concept show a similar effect, except that here the hot and ground are connected to opposite ends of a single conductor. But the effect is the same; the flow of RF current on the hot and ground sides is BALANCED. A quad falls into this category too, along with the simple, single large loop of wire that so many of us have delightedly discovered to be a very effective antenna.

None of these scenarios are helped or redeemed by the artificial ground. This is simply because the antenna and feed-point configuration themselves make the antenna balanced, that is, both hot and ground of the feedline see identical loads, and RF current on the ground side is already automatically maximized.

By the way, I think the phrase "artificial ground" is unfortunate. All RF grounds are artificial, in the sense that they provide an image that balances the actual RF load presented by a given unbalanced antenna. We should, rather, think of it as a "ground tuner," since that is exactly what it is—just like an antenna tuner, it maximizes the flow of RF. When we reach a point where the RF current to antenna, and to ground, are equal, we have maximized our results. The important difference to grasp is that some antennas, like the examples just discussed, provide this balance as a result of their layout and construction. Other scenarios, though, can need quite a bit of help. Often this results in fruitless attempts to improve the radiating element's configuration and performance, when what we really need is a ground image that BALANCES the radiating element.

A Question of Out of Balance

Consider for a moment the ground-mounted vertical antenna. Here is an extreme case, where we have a discrete quarter-wave radiating element, and a hodgepodge of ways to make a ground image underneath it. The literature will tell you to lay out miles of ground radial wires, to either set them slightly into the actual ground or lay them on top of it, to make many, many ground radials, use wire screening instead of single wires, et cetera. All of these are methods of trying to offset the horrendous imbalance inherent in this scenario: A perfectly good quarter-wave radiating element, fed at the bottom, very near to the actual ground—the Earth's crust,

that is.

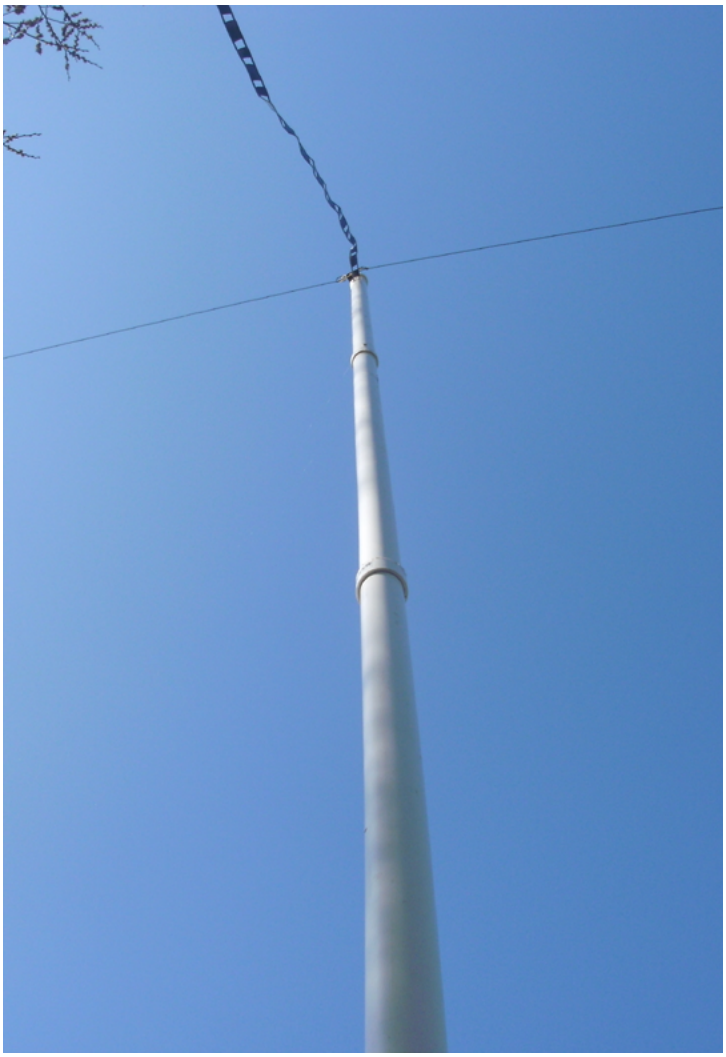
Now, notice what happens when we raise the vertical up in the air, and add just 3 or 4 quarter-wave "ground radials" at the base of the antenna. Suddenly, the huge ocean of ground radial wires is unnecessary, and this "ground plane" vertical can be fed efficiently with coaxial cable. Here too is an important lesson about RF ground. The Earth's crust, itself, is a huge ground—notice how much lightning likes to strike at it!—and, when we get too close to it, RF reflection off of it becomes a huge problem. Thus we have evolved the two main scenarios: Install a dipole at least a half-wave above ground, to minimize reflection losses in the Earth's crust; install a mass of ground radials under a ground-mounted vertical, to make a "screen" between the radiating element and the Earth's crust. In either case, it may be a revelation to realize that this marvelous ground for lightning—the Earth's crust—is, by itself, a horrible RF ground. Lightning ground, yes. AC safety ground, yes. RF ground? In practically any scenario—worse than useless.

Now, don't allow all of this to discourage you. In most real-world situations, the majority of us cannot install, say, an 80 meter dipole a half-wave above ground, simply because most of us don't have two supports that are at least 135 feet tall and 135 feet apart. We're lucky if we have two trees that far apart, and 40 or 50 feet tall. This very low dipole will have reduced efficiency and, due to ground reflection, a lot of the RF goes straight up or nearly so, meaning that it bounces off the ionosphere at a very shallow angle and back to Earth not far from the dipole's location. Some limitations, we just have to accept. But don't be distracted—this is an artifact of ground reflection, which you cannot get around; you can't outrun the math, and you sure can't relocate the Earth's crust. Notice that, since we are talking about a dipole, we have a good RF ground—the side of the dipole connected to the coax's shield. So this situation is as redeemed as we can make it. We can't move or alter the Earth's crust, or make it respond to radiated RF differently.

Artificial Ground Scenarios

The instructions (I found them online and downloaded them) suggest two basic scenarios for using the 931. The first scenario puts the unit between either the transceiver's or the tuner's ground and the station's actual safety ground wire. The second puts the unit between either the transceiver's or the tuner's ground and a counterpoise wire. I've preached more than once about quarter-wave counterpoise wires, how you can cut one for each band, bundle them together, and connect one end of the bundle to tuner ground, taping the far ends and throwing the bundle across the floor. In this second scenario, you now need only a single counterpoise wire, and the 931 will tune it to ground resonance, just like an antenna tuner does with a random wire.

Personally, I don't much like the first scenario; I have all equipment safety grounded to a short (about four feet long) length of bare solid #10 wire, which goes through the window pass-through at my rig location in the basement and to a ground rod just beyond the window. Inserting the 931 between any piece of equipment—rig, tuner, power supply—and safety ground seems like compromising that safety ground. (Can you say "ground loop"?) On the other hand, my multiple counterpoise wires scenario works so well, and is so cheap and simple, that I decided to focus on this method, and try single counterpoise wires of various lengths, and hopefully find one or two that will work on all, or most, HF bands. Note that you can connect multiple counterpoise wires to the 931; the one closest to a quarter-wave will be used, and the others ignored since their reactance is too far outside the 931's tuning range. However, the point here is that, with the 931 as a ground tuner, one or two counterpoise wires should be able to do the job. A lot depends on the length selected; some thought, and experimentation, is in order here.



Big dipole—a balanced antenna. (Photo by author)

Next month, we'll actually put the 931 through some grueling on-air testing, as your CW-addicted antenna columnist tries various random unbalanced antennas to see how well the 931 redeems them. It should be quite interesting—don't miss it! Be careful out there, and I hope to see you on the CW segments. Until next month, my friends, happy operating!

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Antenna Connections

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Artificial Ground, Part Two

Welcome back, my friends. Last month, we talked about the notion of an artificial ground and its applications, and we touched on the fact that yours truly finally bought an artificial ground, the only one on the market—MFJ's Model 931. This time around, we'll discuss the results I garnered when I performed a series of on-air tests with the unit.

Balancing Act

If you missed it last month, an artificial ground comes into play when there is a large discrepancy between the amount of RF current flowing to the antenna and the amount of RF current flowing to RF ground. As we saw in September's column, this can really only happen with what we call unbalanced antennas. It's a fairly easy distinction to make; if the two wires of the feedline, whether coaxial cable or ladder line, are connected to equal and opposite elements, like the two halves of a dipole, say, or the driven element of a beam, then the antenna is balanced. That is to say there are equal, or very nearly equal, paths for hot and ground RF current to flow. Thus there is no discrepancy of ground current, it is equal and opposite to the hot current, and a state of balance exists. A loop raises the ante here by connecting each feedline conductor to one end of a loop of wire, the longer the better. This scenario creates a true balance also.

The problem arises when we step outside of this scenario. Consider, for example, a big dipole fed in the center with ladder line. If we move the ladder line to one end of one wire, and tie the two lines together into one unbroken length, we basically have the venerable Zepp antenna. In this configuration, only one wire of the ladder line is connected, to this single long wire antenna; the other feeder wire simply terminates right there, normally on the other side of an insulator. This beast is a very hard-to-control unbalanced antenna; no route exists for current to flow on the ground side. Tuning will be very difficult, and stray RF will spray everywhere, as ground current searches for a path to flow down. The exception, if it happens at all, will be at or near the frequency where the antenna wire is a half-wave long; the Zepp's original design parameter.

This is why a huge sea of radial wires is so necessary under a ground-mounted vertical; to create a valid ground image, which we now begin to see as simply a path for RF ground current that is as close as possible to being as good as the RF path presented by the vertical itself.

The 931, next to its big brother-in-law, the 969 tuner. (Photo by author)

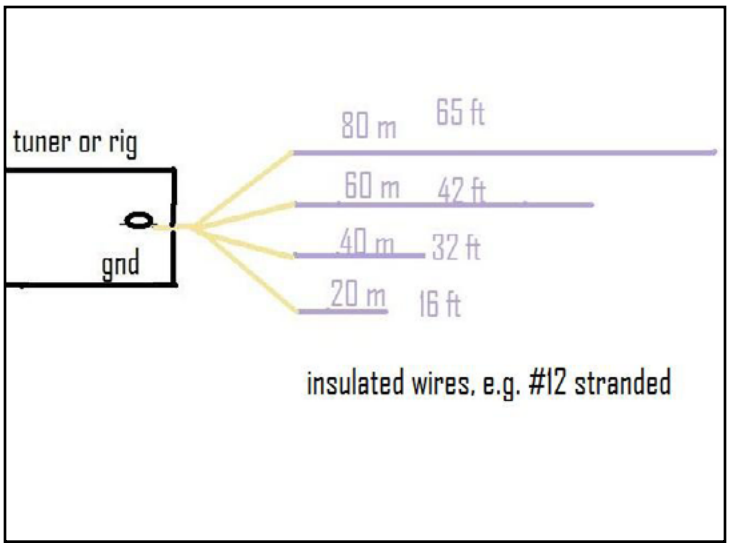
The worst scenario of all, though, is the random wire, which means a single-wire feedline too, which means part of the antenna is in the shack. A very robust RF ground is needed here; without it RF will spray everywhere, burning our fingers when we touch metal objects in the shack while transmitting, burning our lips on metal mike windscreens. Obviously this people fryer is throwing away a lot of RF that we would much rather radiate from the antenna.

THESE are the situations the artificial ground was designed to cure. It is basically an antenna tuner; by connecting a counterpoise length of wire to it, and connecting its input to the tuner's ground connection, we can create a path for equal but opposite RF ground current that mirrors the RF current flowing to the antenna—and maximum efficiency occurs!

As you may have guessed, we're going to guinea pig some of these scenarios, and find out just how effective the artificial ground is in curing the problem.

Before beginning testing, it was necessary to decide which style of using the unit I wanted. You can insert the artificial ground between tuner ground and the station safety ground, and tune the safety ground wire for maximum ground current; or you can connect a length of insulated wire—a counterpoise—to the unit's output, with the input fed from tuner ground. I opted for the counterpoise, partly because I have long advocated for counterpoise wires, a

Green #12 random wire, about 60 feet long. (Photo by author)



The poor man's artificial ground: Counterpoise wires, one-quarter wavelength for each desired band. (Drawing by author)

quarter-wave long, one for each band, tied all together at one end and to the tuner's ground, and partly because I don't like the idea of inserting items in series with any device's safety ground.

Okay! Now we're all on the same page! Ready? Then here we go…

First Scenario: Dupe the Loop

There is no ground-mounted vertical at my QTH, but there is my famous 105-foot loop on the roof, fed at one corner with ladder line. If we tie the two wires of the feedline together at the tuner end, and feed this single wire from the tuner's RANDOM (or WIRE) output, then the ladder line itself becomes the antenna, with the loop at the far end providing a little bit of loading capacitance. My longtime readers will recall that this was also done with the big ladder-line-fed dipole, with the same effect; the feedline becomes a vertical radiator, and the dipole wires become capacitance hats that help load the thing up. This trick was mainly used to operate 160 meters with a dipole that was very short relative to this low frequency. In both cases, though, there is a distinct shortage of ground path for RF ground current to flow down. This scenario promised to be difficult, since the antenna—the ladder line—is only about 11 feet long.

I started off with two counterpoise wires tied to the 931's ground wire jack, one about 16 feet long, the other about 32 feet long. I figured out right away that experimentation is in order here. The straightforward thing to do is simply try various lengths and see what works best at your QTH. You can certainly connect several counterpoise wires to the 931, and the closest one to the right length will be chosen by the unit, just like the scenario with a bundle of counterpoise wires and NO 931.

Right away, I had problems: The 931's meter doesn't work at all! One fellow online had noted poor grounding of the meter circuit board to the case; but I found no issue here, and couldn't see anything else wrong with the meter circuit. So, I found a different way to meter the effect: Watch the ANTENNA TUNER'S dual forward-and-reverse meter while adjusting the 931. Without fail, either a dip in reflected power or a jump in forward power would occur as the unit was adjusted, supporting our main theory, that making the RF ground right is the secret to getting random, unbalanced antennas to work.

As a further comparison, I tried the system with the loop fed normally, from the tuner's balun. Sure enough, I could detect NO difference made by the artificial ground when running the loop normally. Again we demonstrate the principle—a balanced antenna has the ground current well taken care of.

Second Scenario: I'm Fine, Thanks Anyway

As a control subject, I also tried the unit with my coax-fed 20-meter dipole. According to the wisdom we've gathered here, we would expect the artificial ground to be very little help, since we already have a resonant, balanced situation—and indeed the unit has little or no effect here. When we QSY beyond the dipole's bandwidth, the artificial ground begins to show some effect; but it does not lower the increased SWR caused by the lack of antenna resonance. This confirms our original supposition: A resonant antenna, fed with coax, is NOT a candidate for the artificial ground, from the standpoint of improving performance.

Third Scenario: The Random Wire—Taming the Buzzsaw

Here's where it seemed like the artificial ground might do the most good. Single-wire feed is the worst scenario when it comes to excess RF spraying around since, basically, part of the antenna is in the shack. Proper grounding can tame the beast, but it can be hard to accomplish by conventional means.

Also, I must admit, I was curious to see just how effec-

tive such an antenna could be; I haven't run a single, random wire as an antenna since I was a teenager.

So, I grabbed my E-Z Hang and prowled the back yard, looking for a good target. I settled on a nearly horizontal branch, straight east of the basement window that is my antennas pass-through, about 30 feet off the ground and 60 feet from the window. This seemed like a good random wire demonstration, something that others might be able to duplicate or approximate. Also, at 60 feet in length, the wire wouldn't be a quarter-wave, or a multiple thereof, at any ham frequencies (it comes closest to being a quarter-wave at the high end of 80 meters, but it's a little short). The main idea here is, this random length wire with a single-wire feed should really challenge the artificial ground.

Attaching the near end by the kitchen window (straight above my pass-through) I realized that the wire could also be fed at this end with ladder line, like an end-fed Zepp. So, after testing the single-wire feed setup, this short, end-fed Zepp idea was tried too. Man, I LOVE to play with random antennas!

In single-wire feed mode, the random wire was pretty predictable; without the ground dialed in properly, RF sprayed everywhere, making metal in the shack too hot to touch, making the PC and the TV blink, along with the fluorescent lights. For the first time, I had a scenario that was only partially relieved by the artificial ground; I could get sort of close, but not as close as I wanted. Then it occurred to me to disconnect the random length counterpoises I had been testing with and connect my bundle of counterpoises cut to definite quarter-wave lengths for each band (see my March 2016 column). The problem didn't go completely away, but it was greatly reduced.

The 931 does improve slightly on the counterpoise wires; ground can now be tuned to resonance all across any band, instead of the situation I had, where the counterpoises worked well at or near their resonant frequency, with results falling off as I would QSY up or down a given band. Since I generally prefer just the CW portion of a given band, this isn't a problem for me. However, if you want to cover entire bands effectively, the 931, in conjunction with the counterpoise wires, will get you there, or at least a lot closer.

One more thing: When I changed the random wire's feed from single-wire to conventional Zepp feed with ladder line—one wire connected to the antenna, the other one stubbed off—the random wire became much more manageable; the RF spraying around disappeared, receive became much quieter, and this random Zepp multiband antenna worked rather well, thanks to Old Faithful, my MFJ 969 tuner. Here's another lesson I drew, again: ladder line, and a balun equipped tuner, can give you some excellent results with random antennas—even ones connected to only one side of the ladder line!

MFJ 931 artificial ground. (Courtesy: MFJ Enterprises)

it was a new experience for me to adjust the artificial ground and see the antenna tuner's forward power meter swing higher, or the reflected power meter swing lower. This is undeniable evidence that the 931 really is improving the situation by dialing in the ground impedance. Of course, one could just cut more than one counterpoise wire for each band and accomplish nearly the same thing; the 931 does help, but it is not a magic box. You have to work with it and experience a bit of a learning curve with it. Extensive experimenting with various, non-resonant counterpoise lengths may be the real answer here; I tried eight different lengths, some short, some longer, none of them quarter-wavelengths on any band. It could very well be that further experiments here would be fruitful. I was more interested in seeing IF it would work, and HOW WELL it would work. Seriously, if it seems like too much to spend, my old system of a quarter-wavelength counterpoise wire for each band works pretty well, especially when we consider how cheap a few lengths of insulated wire are. I tried some scenarios with listening to shortwave broadcast bands, and the 931 did sometimes give a little boost in received signal strength, which to the hard-core SWL might mean that the 931 is a worthwhile tool to have at the radio position.

I will say that the 931 looks rather cool sitting side by side with its older and heavier brother-in-law, my beloved 969 antenna tuner.

That's all for this month, boys and girls. Join me here in November, when I turn 29 again, and we'll go on another Antenna Jungle safari. Stay safe out there, and happy operating!

Conclusions

The 931's greatest usefulness may be as a teaching tool;

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